

## CLAIMS

What is claimed is:

1. A membrane structure for applying gas to a liquid, comprising:
  - a substantially cylindrical flexible membrane having a generally circular cross section and presenting at least a first zone occupying an arc substantially centered at a north pole location and a pair of second zones occupying arcs adjacent to opposite ends of said first zone; and
    - a plurality of perforations in said first zone and each of said second zones for discharging gas from said membrane, said perforations in each of said second zones presenting a larger collective area as a percentage of the perforated surface area in each of said second zones than the collective area presented by said perforations in said first zone as a percentage of the surface area in said first zone.
2. A membrane structure as set forth in claim 1, wherein said perforations in each of said second zones are larger than the perforations in said first zone.
3. A membrane structure as set forth in claim 2, wherein said perforations in each of said second zones are more numerous per unit of surface area than said perforations in said first zone.
4. A membrane structure as set forth in claim 1, wherein said perforations in each of said second zones are more numerous per unit of surface area than said perforations in said first zone.

5. A membrane structure as set forth in claim 1, wherein:

    said membrane includes a third zone occupying an arc substantially centered at a south pole location on the membrane; and

    said third zone includes a plurality of perforations presenting a larger collective area of perforations as a percentage of the perforated surface area in said third zone than the collective area of perforations presented by said perforations in each of said second zones as a percentage of the perforated surface area in each of said second zones.

6. A membrane structure as set forth in claim 1, wherein:

    said membrane is imperforate on a lower portion thereof occupying an arc of approximately 180° centered at a south pole location on said membrane; and

    said first and second zones are located on an upper portion of said membrane, occupying an arc of approximately 180° centered on said north pole location.

7. A membrane structure as set forth in claim 6, wherein:

    said zones include a pair of third zones occupying arcs adjacent to ends of the respective second zones on said upper portion of the membrane; and

    each of said third zones includes a plurality of perforations presenting a larger collective area of perforations as a percentage of the total perforated surface area in each of said third zones than the collective area of perforations presented by said perforations in each of said second zones as a percentage of the perforated surface area in each of said second zones.

8. A membrane structure as set forth in claim 1, wherein each of said perforations comprises an elongated slit, said slits in said second zones being longer than said slits in said first zone.

9. A membrane structure as set forth in claim 1, wherein:

said perforations comprise elongated slits arranged in separate rows of slits with the slits in each row spaced apart end to end;

said slits in each row have a selected length;

said slits in each row are spaced apart by a selected separation; and

said rows are spaced apart by a selected row spacing.

10. A membrane structure as set forth in claim 9, wherein said slits in said second zones have a greater length than the slits in said first zone.

11. A membrane structure as set forth in claim 9, wherein said slits in said second zone, have a lesser separation than the slits in said first zone.

12. A membrane structure as set forth in claim 9, wherein said slits in said second zones have a lesser row spacing than the slits in said first zone.

13. A tubular membrane diffuser for applying gas to a liquid, comprising:

a rigid diffuser body having a substantially cylindrical shape for receiving the gas and at least one port for discharging the gas;

a flexible membrane sleeved onto said diffuser body, said membrane being substantially circular in cross section and presenting at least a first zone

occupying an arc substantially centered at a north pole location and a pair of second zones occupying arcs adjacent to opposite ends of said first zone; and

a plurality of perforations in said first zone and each of said second zones for discharging gas from said membrane, said perforations in each of said second zones presenting a larger collective area of perforations as a percentage of the perforated surface area in each of said second zones than the collective area of perforations presented by said perforations in said first zone as a percentage of the perforated surface area in said first zone.

14. A diffuser as set forth in claim 13, wherein:

said membrane includes a third zone occupying an arc substantially centered at a south pole location on the membrane; and

said third zone includes a plurality of perforations presenting a larger collective area of perforations as a percentage of the perforated surface area in said third zone than the collective area of perforations presented by said perforations in each of said second zones as a percentage of the perforated surface area in each of said second zones.

15. A diffuser as set forth in claim 13, wherein:

said membrane is imperforate on a lower portion thereof occupying an arc of approximately 180° centered on said south pole location; and

said first and second zones are located on an upper portion of said membrane, occupying an arc of approximately 180° centered on said north pole location.

16. A diffuser as set forth in claim 15, wherein:

said zones include a pair of third zones occupying arcs adjacent to ends of the respective second zones on said upper portion of the membrane; and each of said third zones includes a plurality of perforations presenting a larger collective area of perforations as a percentage of the perforated surface area in each of said third zones than the collective area of perforations presented by said perforations in each of said second zones as a percentage of the perforated surface area in each of said second zones.

17. A diffuser as set forth in claim 13, wherein:

said perforations comprise elongated slits arranged in separate rows of slits with the slits in each row spaced apart end to end; said slits in each row have a selected length; said slits in each row are spaced apart by a selected separation; and said rows are spaced apart by a selected row spacing.

18. A diffuser as set forth in claim 17, wherein said slits in said second zones have a greater length than the slits in said first zone.

19. A diffuser as set forth in claim 17, wherein said slits in said second zones have a lesser separation than the slits in said first zone.

20. A diffuser as set forth in claim 17, wherein said slits in said second zones have a lesser row spacing than the slits in said first zone.

21. A flexible diffuser membrane structure for applying gas to liquid, comprising:

a substantially flat flexible membrane for application to a diffuser body and having a geometric center point, said membrane presenting at least a first zone centered at said point and having a substantially circular periphery and a second zone adjacent to said first zone and having an annular configuration; and

a plurality of perforations in said first and second zones for discharging gas from said membrane, said perforations in said second zone presenting a larger collective area of perforations as a percentage of the perforated surface area in said second zone than the collective area of perforations presented by said perforations in said first zone as a percentage of the perforated surface area in said first zone.

22. A membrane structure as set forth in claim 21, wherein said perforations in said second zone are larger than the perforations in said first zone.

23. A membrane structure as set forth in claim 22, wherein said perforations in said second zone are more numerous per unit of perforated surface area than said perforations in said first zone.

24. A membrane structure as set forth in claim 21, wherein said perforations in said second zone are more numerous per unit of perforated surface area than said perforations in said first zone.

25. A membrane structure as set forth in claim 21, wherein:

said membrane includes a third zone outwardly of said second zone and having an annular shape centered at said point; and  
        said third zone includes a plurality of perforations presenting a larger collective area of perforations as a percentage of the perforated surface area in said third zone than the collective area of perforations presented by said perforations in said second zone as a percentage of the perforated surface area in said second zone.

26. A membrane structure as set forth in claim 21, wherein:

    said perforations comprise elongated slits arranged in separate circles centered at said point and each including a plurality of slits spaced apart end to end;

    said slits in each circle have a selected length;

    the slits in each circle are spaced apart by a selected separation; and

    said circles are spaced apart by a selected circle spacing.

27. A membrane structure as set forth in claim 26, wherein said slits in said second zone have a greater length than the slits in said first zone.

28. A membrane structure as set forth in claim 26, wherein said slits in said second zone have a lesser separation than the slits in said first zone.

29. A membrane structure as set forth in claim 26, wherein said slits in said second zone have a lesser circle spacing than the slits in said first zone.

30. A disk membrane diffuser for applying gas to a liquid, comprising:

a diffuser body presenting a chamber therein for receiving the gas, said chamber being open at the top;

a flexible membrane having a substantially flat and discoidal shape applied to said diffuser body to cover the top of said chamber, said membrane having a geometric center point and presenting at least a first zone centered at said point and having a substantially circular periphery and a second zone adjacent to said first zone and having an annular configuration; and

a plurality of perforations in said first and second zones for discharging gas from said membrane, said perforations in said second zone presenting a larger collective area of perforations as a percentage of the perforated surface area in said second zone than the collective area of perforations presented by said perforations in said first zone as a percentage of the perforated surface area in said first zone.

31. A diffuser as set forth in claim 30, wherein:

said membrane includes a third zone outwardly of said second zone and having an annular shape centered at said point; and

said third zone includes a plurality of perforations presenting a larger collective area of perforations as a percentage of the perforated surface area in said third zone than the collective area of perforations presented by said perforations in said second zone as a percentage of the perforated surface area in said second zone.

32. A diffuser as set forth in claim 30, wherein:

said perforations comprise elongated slits arranged in separate circles centered at said point and each including a plurality of slits spaced apart end to end;

        said slits in each circle have a selected length;

        the slits in each circle are spaced apart by a selected separation; and

        said circles are spaced apart by a selected circle spacing.

33. A membrane structure as set forth in claim 32, wherein said slits in said second zone have a greater length than the slits in said first zone.

34. A membrane structure as set forth in claim 32, wherein said slits in said second zone have a lesser separation than the slits in said first zone.

35. A membrane structure as set forth in claim 32, wherein said slits in said second zone have a lesser circle spacing than the slits in said first zone.

36. A flexible diffuser membrane structure for applying gas to liquid, comprising:

        a substantially flat flexible membrane for application to a diffuser body said membrane presenting at least first and second zones with said first zone being located inwardly of said second zone; and

        a plurality of perforations in said first and second zones for discharging gas from said membrane, said perforations in said second zone presenting a larger collective area of perforations as a percentage of the perforated surface area in said second zone than the collective area of perforations presented by said

perforations in said first zone as a percentage of the perforated surface area in said first zone.

37. A membrane structure as set forth in claim 36, wherein said membrane has a plurality of separate sectors each presenting a generally pie shaped configuration.

38. A membrane structure as set forth in claim 37, wherein said first and second zones are formed by substantially concentric polygons.

39. A membrane structure as set forth in claim 38, wherein said polygons are hexagons.

40. A membrane structure as set forth in claim 39, including:

a third zone presented on said membrane located outwardly of said second zone, said membrane being substantially circular and having a substantially circular periphery at the outside of said third zone; and

a plurality of perforations in said third zone for discharging gas from said membrane, said perforations in said third zone presenting a larger collective area of perforations as a percentage of the perforated surface area in said third zone than the collective area of perforations presented by said perforations in said second zone as a percentage of the perforated surface area in said second zone.

41. A membrane structure as set forth in claim 36, wherein said membrane has a substantially rectangular shape and said first and second zones are formed by substantially concentric rectangles.

42. A membrane structure as set forth in claim 36, wherein:

said perforations comprise elongated slits arranged in separate rows of slits with the slits in each row spaced apart end to end;

    said slits in each row have a selected length;

    said slits in each row are spaced apart by a selected separation; and

    said rows are spaced apart by a selected row spacing.

43. A membrane structure as set forth in claim 42, wherein said slits in said second zone have a greater length than the slits in said first zone.

44. A membrane structure as set forth in claim 42, wherein said slits in said second zone have a lesser separation than the slits in said first zone.

45. A membrane structure as set forth in claim 42, wherein said slits in said second zone have a lesser row spacing than the slits in said first zone.

46. A membrane diffuser for applying gas to a liquid, comprising:

    a diffuser body for receiving the gas;

    a substantially flat flexible membrane applied to said diffuser body, said membrane presenting at least first and second zones with said first zone being located on the membrane inside of said second zone; and

    a plurality of perforations in said first and second zones for discharging gas from said membrane, said perforations in said second zone presenting a larger collective area of perforations as a percentage of the perforated surface area in said second zone than the collective area of perforations presented by said perforations in said first zone as a percentage of the perforated surface area in said first zone.

47. A diffuser as set forth in claim 46, wherein:

said membrane has a generally circular periphery and presents a plurality of generally pie shaped sectors; and

said first and second zones are formed by substantially concentric polygons.

48. A diffuser as set forth in claim 46, wherein said membrane has a substantially rectangular shape and said first and second zones are formed by substantially concentric rectangles.

49. A membrane structure as set forth in claim 46, wherein:

said perforations comprise elongated slits arranged in separate rows of slits with the slits in each row spaced apart end to end;

said slits in each row have a selected length;

said slits in each row are spaced apart by a selected separation; and

said rows are spaced apart by a selected row spacing.

50. A membrane structure as set forth in claim 49, wherein said slits in said second zone have a greater length than the slits in said first zone.

51. A membrane structure as set forth in claim 49, wherein said slits in said second zone have a lesser separation than the slits in said first zone.

52. A membrane structure as set forth in claim 49, wherein said slits in said second zone have a lesser row spacing than the slits in said first zone.